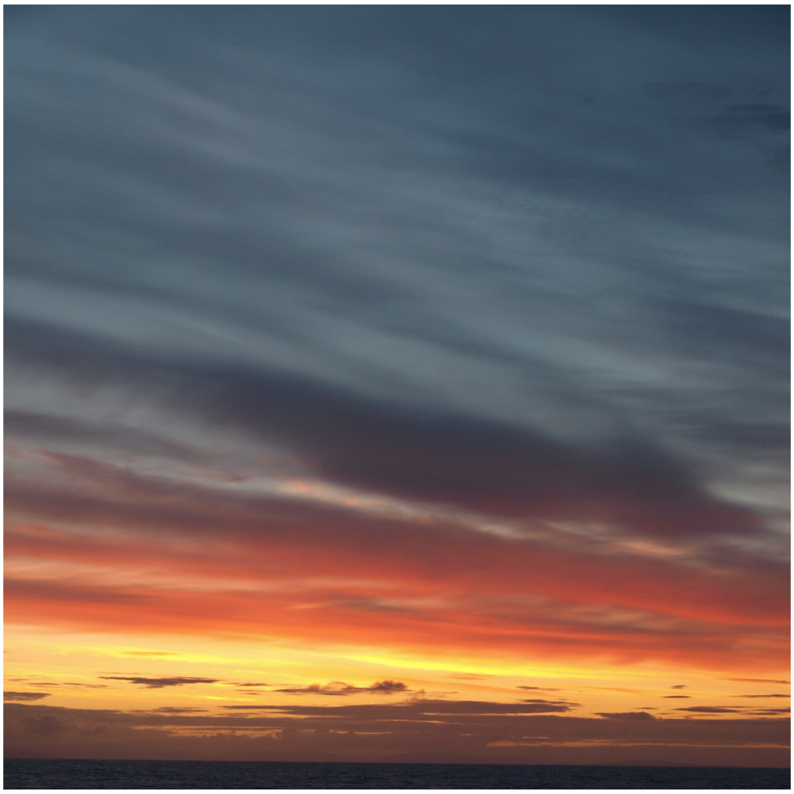
FSS Survey Series: 2009/03

Northwest Herring Summer Acoustic Survey Cruise Report

July 3-22, 2009



RV Celtic Explorer

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1 Introduction

The northwest and west coast (ICES Divisions VIaS & VIIb, c) herring acoustic survey programme was first established in 1994. Prior to acoustic estimation a larval survey programme was conducted between 1981 and 1986. In the early 1990s, the ICES herring working group (HAWG) identified the need for a dedicated herring acoustic survey in this area (Anon, 1994). From 1994 to 1996 surveys were carried out on this stock during the summer feeding phase. In 1997 a two-survey spawning survey was established covering both autumn and winter components. In 2004, a single spawning stock survey was carried out early in quarter 1 and continued until 2007. In 2008, it was decided that this survey should be incorporated into the larger coordinated Malin shelf survey as recommended by SGHERWAY and WGHAWG.

This survey was the second in a new time series and a step away from the traditional spawning stock surveys. The Irish survey was carried out concurrently with the West of Scotland (MarLab) and Irish Sea surveys (AFBI) and was coordinated through the ICES Planning Group of International Pelagic Surveys (PGIPS). Combined survey data on herring distribution, abundance and age will be used to provide a measure of the relative abundance of herring within the Malin shelf stock complex. Survey data on stock numbers at age are submitted to the ICES Herring Assessment Working Group (HAWG) and used in the annual stock assessment process.

The northwest and west coast (ICES Divisions VIaS & VIIb, c) herring stock is composed of 2 of spawning components, autumn and winter spawners. Spawning covers a large geographical area and extends over a 4-month period from late September through to late March (Molloy *et al*, 2000). Traditionally fishing effort has been concentrated on spawning and pre-spawning aggregations. The autumn spawning component, which mostly occurs within VIIb, feeds along the shelf break area to the west of the spawning grounds. In VIaS, summertime distribution extends from close inshore to the shelf break. A component of this the winter spawning fish are known to undertake northward feeding migration into VIaN before returning in the winter to spawn along the Irish coast.

Up to 40 vessels commonly participate in the fishery, many of which are based in the Co. Donegal port of Killybegs. The fleet is made up of 20 RSW (Refrigerated Seawater) vessels of 40-70m in length; 20 polyvalent trawlers 10 of which are vessels of 22-40m and 10 of less then 25m.

2 Materials and Methods

2.1 Scientific Personnel

Organisation	Name	Capacity
FSS	Ciaran O'Donnell	Acoustics (SIC)
FSS	Ryan Saunders	Acoustics
FSS	Eugene Mullins	Acoustics
FSS	Robert Bunn	Acoustics
FSS	Mairead O'Sullivan	Biologist
FSS	Clementine Harma	Biologist
FSS	Marcin Blaszkowski	Biologist (Deck Sci)
FSS	Deirdre Hoare	Biologist
IWDG	Laura Kavanagh	Marine Mammal Obs.

2.2 Survey Plan

2.2.1 Survey objectives

The primary survey objectives of the survey are listed below:

- Carry out a pre-determined survey cruise track based on the known summer herring distribution
- Collect biological samples from directed trawling on fish echotraces to determine age structure and maturity state of survey stock
- Determine an age stratified estimate of relative abundance and biomass of herring within the survey area (ICES Divisions VIIb-c & VIaS) using acoustic survey techniques
- Collect physical oceanography data via a deployed sensor array.

2.2.2 Area of operation and survey design

The survey was focused on the northwest and west coast of Ireland (ICES Divisions VIaS & VIIb-c) as shown in Figure 1. The survey track commenced in the north and worked southwards in continuity.

To keep in line with existing survey methodology (MarLab West of Scotland survey) acoustic surveying was only undertaken between 03:00 and 00:00 (daylight hours).

A systematic parallel transect design was adopted with a randomised start point. Transects were positioned running perpendicular to the lines of bathymetry where possible. Offshore, transects extended to the 250m depth contour and inshore to approximately the 30m depth contour. Transect spacing was set at 3.5 nmi (nautical miles) in the main body of the survey and at 15nmi where transects were interlaced with the Scottish vessel.

In total, the survey accounted for 2,440nmi, with 2,252nmi of data available for acoustic integration. Survey design and methodology adheres to the methods laid out in the PGHERS acoustic survey manual.

2.3 Equipment and system details and specifications

2.3.1 Acoustic array

Equipment settings for the acoustic equipment were determined before the start of the survey program and were based on established settings employed by FSS on previous surveys (O'Donnell *et al.,* 2004). Equipment settings are shown in Table 1.

Acoustic data were collected using the Simrad ER60 scientific echosounder. A Simrad ES-38B (38 KHz) split-beam transducer is mounted within the vessels drop keel and lowered to the working depth of 3.3m below the vessels hull or 8.8m below the sea surface. Three additional operating frequencies were used during the survey (18, 120 and 200kHz) for trace recognition purposes, with the 38KHz data used solely to generate the abundance estimate.

Whilst on survey track the vessel is normally propelled using DC twin electric motor propulsion system with power supplied from 1 main diesel engine, so in effect providing "silent cruising" as compared to normal operations (Anon, 2002). Cruising speed is maintained at a maximum of 10 Kts (knots) where possible. During fishing operations normal 2 engine operations were employed to provide sufficient power to tow the net.

2.3.2 Calibration of acoustic equipment

The ER60 was calibrated in Killary Harbour on the July 18 mid way through the survey. Beam model results were not updated until after the survey. The results of the calibration are presented in Table 1. Prior to this the ER60 was last calibrated in March 2009 (O'Donnell *et al,* 2009).

2.3.4 Acoustic data acquisition

Acoustic data were observed and recorded onto the hard-drive of the processing unit using the equipment settings from previous surveys. The "RAW files" were logged via a continuous Ethernet connection as "EK5" files to the vessels server and the ER60 hard drive as a backup in the event of data loss. In addition, as a further back up a hard copy was stored on an external HDD and copied to DVD. Sonar Data's Echoview® Echolog (Version 4.2) live viewer was used to display the echogram during data collection to allow the scientists to scroll through echograms noting the locations and depths of fish shoals. A member of the scientific crew monitored the equipment continually. Time and location (GPS position) data was recorded for each transect within each survey strata. This log was used to monitor the time spent off track during fishing operations and hydrographic stations plus any other important observations.

2.3.5 Echogram scrutinisation

Acoustic data was backed up every 24 hrs and scrutinised using Sonar data's Echoview® (V 4.2) post processing software. Partitioning of data into the above categories was largely subjective and was viewed by scientists experienced in viewing echograms.

The NASC (Nautical Area Scattering Coefficient) values from each herring region were allocated to one of 4 categories after inspection of the echograms. Categories identified on the basis of trace recognition were as follows:

1. "Definitely herring" echo-traces or traces were identified on the basis of captures of herring from the fishing trawls which had sampled the echo-traces directly, and on large marks which had the characteristics of "definite" herring traces (i.e. very high intensity (red), narrow inverted tear-shaped marks either directly on the bottom or in mid-water and in the case of spawning shoals very dense aggregations in close proximity to the seabed).
2. "Probably herring" were attributed to smaller echo-traces that had not been fished but which had the characteristic of "definite" herring traces.
3. "Herring in a mixture" were attributed to NASC values arising from all fish traces in which herring were thought to be contained, owing to the presence of a proportion of herring within the nearest trawl haul or within a haul which had been carried out on similar echo-traces in similar water depths.

4. "Possibly herring" were attributed to small echo-traces outside areas where fishing was carried out, but which had the characteristics of definite herring traces.

The "EK5" files were imported into Echoview for echo post-processing. The echograms were divided into transects. . Echo integration was performed on a region which were defined by enclosing selecting marks or scatter that belonged to one of the four categories above. The echograms were analysed at a threshold of -70 dB and where necessary plankton was filtered out by thresholding at –65 dB.

The allocated echo integrator counts (NASC values) from these categories were used to estimate the herring numbers according to the method of Dalen and Nakken (1983).

The following TS/length relationships used were those recommended by the acoustic survey planning group (Anon, 1994):

Herring	TS = 20logL – 71.2 dB per individual (L = length in cm)
Sprat	TS = 20logL – 71.2 dB per individual (L = length in cm)
Mackerel	TS = 20logL – 84.9 dB per individual (L = length in cm)
Horse mackerel	TS = 20logL – 67.5 dB per individual (L = length in cm)

The TS length relationship used for gadoids was a general physoclist relationship (Foote, 1987):

Gadoids	TS = 20logL – 67.5 dB per individual (L = length in cm)

For boarfish (*capros aper*) the TS/length relationships used for herring was applied in place of a species specific TS. Once an accurate TS for boarfish has been verified then this will be applied retrospectively to the data.

Boafish	TS = 20logL – 71.2 dB per individual (L = length in cm)

The same categories were applied to other target pelagic species encountered during the survey. Selection criteria are based primarily upon the species composition of trawl samples as well as target strength (TS) information.

2.3.6 Biological sampling

A single pelagic midwater trawl with the dimensions of 19m in length (LOA) and 6m at the wing ends and a fishing circle of 330m was employed during the survey (Figure 11). Mesh size in the wings was 1.6m through to 2cm in the cod-end. The net was fished with a vertical mouth opening of approximately 8m, which was observed using a cable linked "BEL Reeson" netsonde (50 kHz). The net was also fitted with a Scanmar depth sensor. Spread between the trawl doors was monitored using Scanmar distance sensors, all sensors being configured and viewed through a Scanmar Scanbas system.

All components of the catch from the trawl hauls were sorted and weighed; fish and other taxa were identified to species level. Fish samples were divided into species composition by weight. Species other than the herring were weighed as a component of the catch and length and weight measurements were taken for 100 individuals in addition to a 300 fish length frequency sample. Age, length, weight, sex and maturity data were recorded for individual herring within a random 100 fish sample from each trawl haul with a further 100 random length and weight measurements were also taken in addition to a 300 fish length frequency sample. All herring were aged onboard. The appropriate raising factors were calculated and applied to provide length frequency compositions for the bulk of each haul.

Decisions to fish on particular echo-traces were largely subjective and an attempt was made to target marks in all areas of concentration not just high density shoals. No bottom trawl gear was used during this survey.

2.3.7 Oceanographic data collection

Hydrographic stations were carried out during the survey at predetermined locations along the track. Data on temperature, depth and salinity were collected using a Seabird 911 sampler from 1m subsurface to full depth.

2.4 Analysis methods

2.4.1 Abundance estimates

Total abundance, N_T, is given by $\sum_{m}^{Mark-types} N_{T,m}$, the sum over the total abundance by mark-types.

$$N_{T,m} = \sum_{s}^{strata} N_{m,s}$$

Suppressing the mark-type index, m, the stratum abundance is

$$N_s = area_s \sum_{l}^{transects} \bar{n}_{s,t} l_{s,t} \Big/ \sum_{j} l_{s,j}$$

,where l is the transect length and $\bar{n}$ is the transect mean abundance n.mi^{-2} which is given by

$$\sum_{j}^{track\cdot fragments} n_{s,t,j} d_{s,t,j} \Big/ l_{s,t}$$

, where d is the distance of the track fragment and $n_{s,t,j}$ is the mean abundance n.mi^{-2} for the jth track fragment.

Because hauls are assigned with there own stratification that will not necessarily coincide with the acoustic strata, the conversion of NASC into mean density is done at the track fragment level, usually a 1 n.mi segment, but these could be just for the schools themselves. The haul assigned, $h_{m,s,t,j}$, depends strongly on the mark-type (m) and since more than one school can be in a track fragment it needs to be specified. Since age and maturity length-keys are to be applied, the basic estimation is mean density by length bins. The $n_{s,t,j}$ is found by summing over the $n_{s,t,j}$.

$$n_{t,j,i} = \frac{NASC_{t,j}}{\bar{\sigma}_{h_{m,t,j}}} p_{i,h_{m,t,j}}$$

, where i indexes length bins, p_i is the proportion of herring in the i^{th} length bin, and is given by $\sum_{spe}^{species} \sum_{i} p_{spe,i} 10^{(a+b\log 10(L_{spe,i}))/10}$

, where $p_{spe,i}$ applies over all species considered in the haul, $L_{spe,i}$ is the length to use for the i^{th} length bin and the data comes from the haul (of combination of hauls) assigned, $h_{m,t,j}$. For non-mix mark-types, the later simplifies to

$$\sum_{i} p_{herring,i} 10^{(073+20\log 10(L_{herring,i}))/10}.$$

For biomass, a mean weight is also applied to the $n_{t,j,i}$ using the estimated regression relationship, a L_i^b.

For abundance by age and maturity, the abundance by length bin, $n_{t,j,i}$, is averaged over track fragments and then transects to give a strata (and mark-type) mean. The age and maturity keys are applied to the results.

$V_s = area_s^2 s_s^2 W_s$, where $W_s = \sum_{l}^{transects} l^2{}_{s,t} \Big/ (\sum_{j} l_{s,j})^2$ and s^2 is the sample variance.

The variance for the total is the sum of strata variances.

The total biomass can be obtained directly from the track fragment mean biomass by $B_T = \sum_k^{track \cdot fragment} \overline{n}_k w_k$, where w_k is a factor that takes into account the factors for transect and strata averaging, i.e., $w_k = \frac{1 n.mi}{l_{t_k}} \frac{l_{t_k}}{\sum_t^{stratum.s_k} l_{s_k,t}} area_{s_k} = \frac{1}{\sum_t^{stratum.s_k} l_{s_k,t}} area_{s_k}$

, where the 1 n.mi is the length of the track fragment. This ignores the mark-type since that is already accounted for in the $\overline{n}_k$. The $\overline{n}_k w_k$ is the biomass from a track fragment and they can then be used to map the biomass at a fine spatial scale.

Estimates are made for SSB, total abundance and biomass, abundance by age (ring counts), and abundance by age x length bins. A cv (based on strata standard error divided by the strata mean) is estimated for SSB, total abundance and biomass, and abundance by age.

3 Results

3.1 Herring abundance and distribution

Thirty one hauls were carried out over the course of the survey of which 13 contained herring (Figure 2, Table 2). Herring schools close to the surface proved very difficult to catch and as a result only a few successful trawls were made. As a result the number of valid herring samples (n=>100) was low (3). Over 900 length measurements of herring were taken and 347 individual were aged during the survey.

3.1.2 Herring biomass and abundance

A full breakdown of the survey stock structure is presented by distribution, age, length, biomass, abundance and area in Tables 4, 5 & 6 and Figures 3 & 4.

Herring	Millions	Biomass (t)	% contribution
Total estimate			
Definitely	328	24,760	53.3
Mixture	26	6,126	13.2
Probably	194	15,574	33.5
Total estimate	**548**	**46,460**	100
Possibly	-	-	
Possible estimate			
SSB Estimate			
Definelty	68	8,717	41.7
Mixture	26	6,126	29.3
Probably	44	6,063	29.0
SSB estimate	**138**	**20,906**	100

3.1.3 Herring distribution

A full breakdown of school categorisation, number and biomass and abundance by strata is provided in Table 9.

In VIaS, herring were found distributed on the shelf between 55-56ºN. Schools in this area were observed mainly as single midwater/surface spikes in the mid-shelf area (Figure 6c). Single schools that were successfully targeted were found to be composed mainly of small juvenile fish and a low proportion of mature individuals from 16.5-27.5cm (Figures 2 & 3, Table 3). Due to the difficulties in successfully catching herring samples in this area the accuracy length profile data should be considered and may not be a true representation of the school composition.

Towards the shelf break in VIaS herring were observed as mixed schools often occurring over a very wide area (Figure 6a). The pattern of school type and distribution is similar to 2008. However, in the northern reaches along the shelf break area some very large high density scattering layers containing small amounts of herring were observed. One of which was in excess of 14nmi long stretching from the 120-250m depth contours. Trawl samples from these layers yielded very small amounts of herring (2 individuals per sample) and a much greater contribution of mackerel. Due to the high density of this scattering layer, the high density of plankton and the mix of fish and non-fish species it was impossible to accurately determine the proportion of herring contained within these layers. As a result it was decided that no allocations should be made to herring.

In VIIb, herring were found distributed along the shelf break around the 54ºN within a localised area (Figure 3). Herring on the shelf break were found mixed with mackerel that were in various stages of spawning (Figure 6a). Samples from VIIb ranged from 25-31cm overall and were distinctly different from those further north. The age profile of herring in VIIb showed a similar profile to the expected age composition as observed in 2008.

In 2008, the highest density registrations were also encountered along the shelf break area in VIIb. However, in 2008 a relatively high number of small herring schools were also found distributed in shallow waters on-shelf close to the autumn spawning grounds. In 2009, these small on-shelf schools were absent and it is thought that migration westward to the shelf edge feeding grounds had already taken place.

3.1.4 Herring stock structure

Age analysis of biological samples showed herring within the survey area to be composed of age from 1-9 years (winter rings), as shown in Figure 4 and Table 4. Over 86% of the total stock biomass was located in VIaS in the regions associated with mainly winter spawners. The remaining 14% of the total biomass was located in VIIb a region more associated with autumn spawners.

Areas combined, the stock appears dominated by 1 winter ring fish which contribute 55.7% of the biomass and 76% of the abundance estimate. Combined these two year classes represent over 78% of the total biomass observed during the survey. The next most dominate year class is the 2 winter ring which make up over 22% of the biomass and 15% of total abundance. The 4, 7, and 5 winter ring fish make up the remaining ranked year classes. However, the high proportion of total biomass in VIaS and the associated low age profile distorts the overall profile of the estimate.

The dominant year classes from the 2008 survey were the 2 and 3 winter ring fish and contributed 25% and 24% of the total biomass respectively. In 2009 these year classes are largely under represented as the now 3 and 4 winter ring fish. Weak signs of the 4 winter ring fish are visible but not in the numbers that would be expected. The age profile of herring within VIIb are as would be expected based on the 2008 survey results and from commercial catch data.

Maturity analysis indicates over 55% of the total biomass to be immature, which represents over 74% of the abundance estimate. Of the remaining biomass 45% of which was mature 27% is accounted for by the stage 3 (maturing) fish which were mostly located within VIIb in the region associated with autumn spawners and 15% of stage 8 (spent) fish that were located further north in the winter spawning region.

3.2 Secondary species

Boarfish

Boarfish (Capros aper) were encountered almost exclusively along the shelf break from 120-250m depth between the 53-54ºN line of latitude as clean single high density schools (Figure 5 & 6d). Boarfish schools once positively identified were easily discernable from other species. Over 720 individual length measurements and 303 length/weight measurements were recorded. Length ranged between 10.5-17.5cm, with a mean length and weight of 12.7cm and 47g respectively.

A full breakdown of school number and biomass and abundance by strata is provided in Table 10.

Boarfish	**Millions**	**Biomass (t)**	**% contribution**
Total estimate			
Definitely	2000.0	21,697	100.0
Mixture	0	0	0
Probably	0	0	0
Total estimate	2000	21,697	100

Mackerel
Mackerel were the most commonly observed species on the survey and were found in 94% of hauls. Mackerel were distributed over the entire survey area as single species schools and also in mixed layers. On the shelf, schools of mixed size classes were encountered which tended to be composed of smaller individuals. These on-shelf schools ranged from low to high density. Further offshore towards the shelf break, larger fish in various spawning stages were encountered as both single and mixed schools. These schools were generally of high density. Mixed species aggregations of very high density were observed in the northern reaches of the survey. The fish component of these aggregations was composed mainly of mackerel and aggregations of over 14 nmi were observed (Figure 6b). In total 4,125 individual length measurements were taken for mackerel. Lengths ranged from 20-42cm with a mean length of 26.9cm relating to a mean weight of 176g.

Horse mackerel
Horse mackerel were found distributed over both the shelf break and shelf areas. Between 54-55ºN schools were found on the shelf around the Donegal Bay area as small medium to high density single species schools over patches of rough ground. The 2001 year class was well represented in trawl samples. In total 1,105 individuals were measured and 688 length/weight measurements were taken.

3.3 Oceanography

In total 27 CTD casts were made during the survey (Figure 7). All data were compiled to produce horizontal plots of temperature and salinity at the following depths; 5m subsurface, 20m, 40m and 60m (Figures 8-11 respectively).

Overall, surface waters appear warmer and fresher than last year and the water column is more stratified with regards to temperature with a defined strong thermocline. A warm fresh water lens is a prominent feature very from data recorded at the 20m around Donegal Bay area (Figure 9). In deeper waters the West Irish Shelf Front is visible through the tightening of the isohalines off Mayo and provides a good indication of that position of this front is similar to 2008 (Figure 11).

The Islay Front in the northern survey area is the most noticeable feature in surface waters north of Malin Head (Figure 8). This is a well-documented front that separates Atlantic water from the Irish Sea.

4 Discussion and Conclusions

4.1 Discussion

Overall, the survey was a success with no time losses due to poor weather or mechanical failure. Survey aims were not achieved as planned due to the vessel not being permitted to enter UK waters. This resulted in the planned transect interlacing with the Scottish (FV *Quantus*) and Northern Ireland (RV *Corystes*) vessels being dropped. The cruise plan was adjusted and survey effort was re-allocated back into Irish waters.

The biomass of herring observed was overall higher than in 2008 by over 4% but distribution showed a similar pattern. The bulk of the stock was located in VIaS and thought to be composed of winter spawners. However, the age structure of the stock was markedly different from 2008. This can be directly attributed to the small number of valid trawl samples caught during the survey which were used to determine the age structure of the stock. Two valid trawl samples used to generate the biomass for area VIaS, which represented over 86% of the total biomass. Both of these samples contained a high proportion of juveniles and thus were weighted heavily during the analysis. A third valid trawl sample containing a very similar length profile from VIaS was omitted from the analysis due to the small number of fish (n=31) but followed the same length profile. The issue of catchability should be considered in terms of whether the length profile of the samples were indeed representative of the length profile of the target school and that perhaps the larger individual's evaded capture. The age structure of herring located in VIIb (autumn spawners) can be considered more robust and shows a similar pattern to the 2008 survey and also commercial catch data.

Signals of recruiting year class observed in VIaS were picked up from commercial samples in quarter one but not in the proportions displayed here. As a result the estimate should be treated with a high degree of caution especially in relation to the disaggregated age data.

The high density large aggregations of mixed species observed in the northern shelf area (VIaS), although found to contain very small numbers of herring, were not allocated any herring biomass during the analysis. This was decided as the proportion of herring within these schools could not be determined with a degree of accuracy from trawl samples or through acoustic thresholding. To include allocations of these aggregations would have led to a gross over estimate of the stock. As a result biomass of herring within the VIaS region may be an underestimate.

The distribution of small on-shelf herring schools observed in the northern area of VIIb in 2008 were absent in 2009. Although of low acoustic density individually, combined these small schools contributed significantly to the overall stock biomass. Reports from fishermen indicated that herring had been in Donegal Bay in June but had since left. The absence of these schools may be attributed to the difference in water temperature noted in 2008-2009 which may have prompted an earlier migration to feeding grounds either to the west or north of the Bay. Overall, SST was over 1.5ºC higher in 2009 than at the same time in 2008. Horse mackerel were found distributed over the shelf areas in and around the Donegal Bay area and historically would aggregated in August in this area. The early migration of herring and the early appearance of horse mackerel may also be an indicator of the warmer SST observed in 2009.

4.2 Conclusions

The 2009 herring estimate is similar to that observed in 2008 in terms of biomass. Without a longer time series it is impossible to observe any trends at this stage. The biomass itself could be an underestimate due to the omission of an unquantifiable component of herring in the northern area.

The age structure as determined from the few successful trawl samples is not considered representative of the actual structure of the stock. The results from the 2008 survey showed good alignment with the commercial catch data. The results of the 2009 survey should be compared to the quarter four and quarter one commercial catch data to help determined validity.

As a result the estimate for herring in VIIb can be considered relatively robust in temrs of biomass and abundance, even though only a single sample was used to determine the age profile. The VIaS estimate should be treated with a high degree of caution especially in relation to the disaggregated age data.

Acknowledgements

We would like to express our thanks and gratitude to Dennis Rowan (Captain) and crew of the Celtic Explorer for their good will and professionalism during the survey.

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Table 1. Survey settings and calibration report (38KHz) for the Simrad ER60 echosounder. Northwest herring survey, July 2009.

Vessel :	R/V Celtic Explorer	Date :	17/07/2009
Echo sounder :	ER60 PC	Locality :	Killary Harbour
Type of Sphere : CU-60	TS_{Sphere}: -33.50 dB (Corrected for soundvelocity or t,S)	Depth(Sea floor) :	34 m

Calibration Version 2.1.0.11

Comments:
Killary Harbour, Flat Calm @ 08:30am

Reference Target:

TS	-33.50 dB	Min. Distance	15.00 m
TS Deviation	5.0	Max. Distance	25.00 m

Transducer: ES38B Serial No. 30227

Frequency	38000 Hz	Beamtype	Split
Gain	25.73 dB	Two Way Beam Angle	-20.6 dB
Athw. Angle Sens.	21.90	Along. Angle Sens.	21.90
Athw. Beam Angle	7.05 deg	Along. Beam Angle	6.96 deg
Athw. Offset Angle	-0.01 deg	Along. Offset Angl	-0.07 deg
SaCorrection	-0.73 dB	Depth	8.80 m

Transceiver: GPT 38 kHz 009072033933 2 ES38B

Pulse Duration	1.024 ms	Sample Interval	0.193 m
Power	2000 W	Receiver Bandwidth	2.43 kHz

Sounder Type:
EK60 Version 2.2.0

TS Detection:

Min. Value	-50.0 dB	Min. Spacing	100 %
Max. Beam Comp.	6.0 dB	Min. Echolength	80 %
Max. Phase Dev.	8.0	Max. Echolength	180 %

Environment:

Absorption Coeff.	8.9 dB/km	Sound Velocity	1507.9 m/s

Beam Model results:

Transducer Gain =	25.71 dB	SaCorrection =	-0.63 dB
Athw. Beam Angle =	7.00 deg	Along. Beam Angle =	6.97 deg
Athw. Offset Angle =	-0.02 deg	Along. Offset Angle=	-0.06 deg

Data deviation from beam model:
RMS = 0.14 dB
Max = 0.40 dB No. = 133 Athw. = 3.2 deg Along = -3.4 deg
Min = -1.46 dB No. = 18 Athw. = -4.1 deg Along = -0.9 deg

Data deviation from polynomial model:
RMS = 0.11 dB
Max = 0.39 dB No. = 133 Athw. = 3.2 deg Along = -3.4 deg
Min = -1.45 dB No. = 18 Athw. = -4.1 deg Along = -0.9 deg

Comments :
Flat Calm, good overall conditions
Wind Force : 2 kn. **Wind Direction :** NW
Raw Data File: F:\Northwest Herring 2009\Calibration files\NWHAS_09-D20080620-T084011.raw
Calibration File: H:\ER-60\Calibrations 2009\38Khz Killary 17.07.09

Calibration: Ciaran O'Donnell

Table 2. Catch composition and position of hauls undertaken by the RV *Celtic Explorer*. Northwest herring survey, July 2009.

No.	Date	Lat. N	Lon. W	Time	Bottom (m)	Target (m)	Bulk Catch (Kg)	Herring %	Mackerel %	Scad %	Sprat %	Others* %
1	04.07.09	55 49.04	008 52.20	08:48	122	0-20	164.0	0.1	99.6			0.3
2	04.07.09	55 49.05	008 23.29	12:15	135	0-20	9.2	2.4	96.9			0.7
3*	04.07.09	55.49.07	007 45.48	16:24	132	0-11	1.5		100.0			
4*	04.07.09	55 51.01	007 31.16	21:41	82	0-12	183.4	0.1	99.9			
5*	05.07.09	55 45.13	009 08.21	10:54	124	30	5.0		94.0			6.0
6	05.07.09	55 48.10	007 25.50	18:00	59	34	1000.0	31.8	68.2			
7*	06.07.09	55 29.44	009 14.67	11:48	134	14	2.0		100.0			
8	06.07.09	55 29.35	008 12.35	16:34	83	55-68	700.0	75.7	24.3			
9	07.07.09	55 24.66	008 37.00	08:50	95	25	21.0	1.0	98.0			1.0
10*	07.07.09	55 22.39	009 27.11	16:30	150	0-20	1.5					100.0
11	08.07.09	55 18.90	008 36.10	10:52	96	85	450.0	1.0	99.0			
12	08.07.09	55 15.31	009 43.07	18:00	132	35	20.9		98.1	1.9		
13*	08.07.09	55.08.52	009.48.07	14:20	123	0-15	15.0	3.3	96.7			
14*	09.07.09	55 05.07	008 55.14	23:00	86	60	20.6	1.6	92.5	4.9		1.0
15*	10.07.09	55 05.00	009 07.48	05:04	101	45	250.0		100.0			
16*	10.07.09	55.01.37	009.07.04	14:19	83	0-9	0.8	93.1			6.9	
17	11.07.09	55.50.91	009.15.87	14:46	88	0-14	250.0		99.7	0.3	0.1	
18	12.07.09	54 47.39	008 44.42	08:10	65	8	300.0		100.0			
19	12.07.09	54.43.81	010 14.18	19:00	123	25-35	450.0		70.9	29.1		
20	13.07.09	54 33.39	010 20.16	19:44	120	90	270.0		80.8	19.2		
21	14.07.09	54.30.13	010.41.44	14:00	233	16-35	112.6		97.4	2.6		
22	14.07.09	54 26.63	010 21.06	22:00	82	0-10	62.4	0.3	84.6	0.8	0.1	14.2
23	15.07.09	54 26.49	009 00.53	04:53	63	0-10	900.0		98.2	1.3		0.6
24	15.07.09	54.19.59	010.28.74	16:00	144	0-15	19.9		74.6	17.5		7.9
25	16.07.09	54 05.57	010 40.14	10:21	185	0-12	188.0	11.3	49.7	15.9		23.1
26	16.07.09	54.02.05	010.52.17	16:15	185	0-20	107.0	0.3	35.0	18.5		46.2
27	16.07.09	53 58.57	010 41.55	21:10	128	100	391.6		52.6	40.1		7.3
28	17.07.09	53 55.02	011 13.57	08:25	230	170	200.0		14.0	5.0		81.0
29	18.07.09	53 37.37	011 20.97	20:16	198	0-15	400.0		21.98	65.4		12.61
30	19.07.09	53 33.71	011 21.32	10:32	178	80	47.1		24			76
31*	20.07.09	53 19.73	010 14.00	12:10	101	70	5.5		8		50	42

* Indicates target schools not represented in the catch.

Table 3. Length frequency (%) of herring hauls used in the analysis. Northwest herring survey, July 2009.

Haul # Length	6	8	25	Totals
16.5	1.0			1
17	3.2	1.5		5
17.5	8.7	2.4		11
18	14.9	11.8		27
18.5	19.4	16.6		36
19	10.7	17.8		28
19.5	10.0	13.0		23
20	5.5	6.8		12
20.5	2.3	3.8		6
21	3.6	3.6		7
21.5	1.3	2.7		4
22	1.3	2.1		3
22.5	1.6	3.0		5
23	1.0	4.4		5
23.5	4.5	4.1		9
24	2.6	1.8		4
24.5	2.9	2.1		5
25	1.3	0.6	0.5	2
25.5	1.9		0.5	2
26	1.3	1.2	0.5	3
26.5	1.0		1.9	3
27		0.3	6.2	6
27.5		0.6	3.8	4
28			19.0	19
28.5			19.9	20
29			24.6	25
29.5			13.7	14
30			7.1	7
30.5			1.9	2
31			0.5	0
Totals	100	100	100	

Table 4. Herring length at age (winter rings) as abundance (millions) and biomass (000's tonnes). Northwest herring survey, July 2009.

Length	Age (Rings)											Abundance	Biomass	Mn wt
(cm)	0	1	2	3	4	5	6	7	8	9	10	(millions)	000's t	(g)
16.5	-	2.5	-	-	-	-	-	-	-	-	-	2.51	0.1	39.5
17	-	12	-	-	-	-	-	-	-	-	-	12.19	0.53	43.5
17.5	-	29	-	-	-	-	-	-	-	-	-	28.69	1.37	47.8
18	-	69	-	-	-	-	-	-	-	-	-	69.08	3.62	52.3
18.5	-	93	-	-	-	-	-	-	-	-	-	93.03	5.32	57.2
19	-	74	-	-	-	-	-	-	-	-	-	73.53	4.59	62.4
19.5	-	60	-	-	-	-	-	-	-	-	-	59.61	4.04	67.9
20	-	32	-	-	-	-	-	-	-	-	-	31.82	2.34	73.7
20.5	-	14	1.4	-	-	-	-	-	-	-	-	15.81	1.26	79.8
21	-	18	-	-	-	-	-	-	-	-	-	18.38	1.59	86.3
21.5	-	10	-	-	-	-	-	-	-	-	-	10.24	0.95	93.2
22	-	2.9	5.8	-	-	-	-	-	-	-	-	8.7	0.87	100.4
22.5	-	-	12	-	-	-	-	-	-	-	-	11.84	1.28	108
23	-	-	14	-	-	-	-	-	-	-	-	14	1.62	116
23.5	-	-	12	7.5	2.5	-	-	-	-	-	-	22.42	2.79	124.4
24	-	-	11	-	-	-	-	-	-	-	-	11.28	1.5	133.2
24.5	-	-	13	-	-	-	-	-	-	-	-	12.88	1.84	142.5
25	-	-	3.7	1.2	-	-	-	-	-	-	-	4.87	0.74	152.2
25.5	-	-	3.4	-	1.7	-	-	-	-	-	-	5.16	0.84	162.3
26	-	-	3.3	-	3.3	-	-	-	-	-	-	6.55	1.13	172.9
26.5	-	-	0.7	1.5	0.7	-	-	-	-	-	-	2.94	0.54	184
27	-	-	0.4	-	1.3	0.4	-	0.4	-	-	-	2.66	0.52	195.5
27.5	-	-	-	0.2	1.1	1	0.5	-	-	-	-	2.7	0.56	207.5
28	-	-	-	0.8	2.4	1.3	1.3	-	-	-	-	5.83	1.28	220.1
28.5	-	-	-	0.3	1.5	1.8	0.6	1.8	-	-	-	6.13	1.43	233.2
29	-	-	-	-	0.5	1.4	2.9	2.4	-	0.5	-	7.59	1.87	246.8
29.5	-	-	-	-	-	1.5	1.2	1.5	-	-	-	4.23	1.1	260.9
30	-	-	-	-	-	-	0.4	1.1	0.4	0.4	-	2.19	0.6	275.6
30.5	-	-	-	-	-	0.2	0.2	0.2	-	-	-	0.58	0.17	290.8
31	-	-	-	-	-	0.1	0.1	0.1	-	-	-	0.15	0.04	306.7
SSN	-	18	70	11	15	7.7	7.1	7.5	0.4	0.8	-	**137.92**	-	-
SSB	-	1.5	9.3	1.7	2.8	1.8	1.7	1.9	0.1	0.2	-	-	**20.9**	-
Mn wt (g)	-	62	128	146	185	235	244	249	276	259	-	-	-	-
Mn L (cm)	-	19	24	25	27	29	29	29	30	30	-	-	-	-

Table 5. Total biomass (000's tonnes) of herring at age (winter rings), by strata as derived from acoustic estimate of abundance**.** Northwest herring survey, July 2009.

Strata	0	1	2	3	4	5	6	7	8	9	10	Total
40 D9	0	2.3	0.9	0.1	0.1	0	0	0	0	0	0	3.5
40 E0	0	0.3	0.1	0	0	0	0	0	0	0	0	0.4
40 E1	0	12.6	5.1	0.8	0.8	0	0	0	0	0	0	19.4
39 D9	0	8.2	3.2	0.3	0.4	0.1	0	0	0	0	0	12.2
39 E0	0	2.5	1	0.1	0.1	0	0	0	0	0	0	3.7
39 E1	0	0.1	0	0	0	0	0	0	0	0	0	0.1
38 E0	0	0	0	0	0	0	0	0	0	0	0	0
38 D9	0	0	0	0	0	0	0	0	0	0	0	0
38 D8	0	0	0	0	0.2	0.3	0.3	0.3	0	0	0	1.1
37 E0	0	0	0	0	0	0	0	0	0	0	0	0
37 D9	0	0	0	0	0	0	0	0	0	0	0	0
37 D8	0	0	0.1	0.2	1.1	1.4	1.4	1.5	0.1	0.2	0	6
36 D8	0	0	0	0	0	0	0	0	0	0	0	0.1
36 D7	0	0	0	0	0	0	0	0	0	0	0	0
35 D8	0	0	0	0	0	0	0	0	0	0	0	0
35 D7	0	0	0	0	0	0	0	0	0	0	0	0
Total	0	25.90	10.40	1.70	2.80	1.80	1.70	1.90	0.10	0.20	0.00	46.50
%	0	55.70	22.40	3.60	6.00	3.90	3.70	4.00	0.20	0.50	0.00	100.00

Table 6. Herring abundance (millions) at age (winter rings), by strata as derived from acoustic estimate of abundance. Northwest herring survey, July 2009.

Strata	0	1	2	3	4	5	6	7	8	9	10	Total
40 D9	0	36.36	7.42	0.71	0.65	0.12	0.05	0.02	0	0	0	45.32
40 E0	0	4.04	0.82	0.08	0.07	0.01	0.01	0.00	0	0	0	5.03
40 E1	0	209.36	38.47	5.99	5.27	0.01	0.00	0.00	0	0	0	259.1
39 D9	0	127.36	25.98	2.48	2.29	0.41	0.17	0.08	0	0	0	158.76
39 E0	0	38.24	7.80	0.75	0.69	0.12	0.05	0.02	0	0	0	47.7
39 E1	0	0.99	0.18	0.03	0.03	0	0	0	0	0	0	1.2
38 E0	0	0	0	0	0	0	0	0	0	0	0	0
38 D9	0	0	0	0	0	0	0	0	0	0	0	0
38 D8	0	0	0.09	0.22	0.94	1.10	1.05	1.14	0.06	0.13	0	4.7
37 E0	0	0	0	0	0	0	0	0	0	0	0	0
37 D9	0	0	0	0	0	0	0	0	0	0	0	0
37 D8	0	0	0.50	1.15	5.02	5.87	5.65	6.12	0.30	0.69	0	25.3
36 D8	0	0	0.01	0.02	0.09	0.11	0.10	0.11	0.01	0.01	0	0.5
36 D7	0	0	0	0	0	0	0	0	0	0	0	0
35 D8	0	0	0	0	0	0	0	0	0	0	0	0
35 D7	0	0	0	0	0	0	0	0	0	0	0	0
Total	0	416.3	81.26	11.42	15.05	7.74	7.08	7.50	0.37	0.84	0.00	547.59
%	0	76.03	14.84	2.09	2.75	1.41	1.29	1.37	0.07	0.15	0.00	100
Cv (%)	NA	39.6	39.4	35.6	32.8	51.2	53.7	54.8	55.8	55.7	NA	NA

Table 7. Herring biomass (000's tonnes) at maturity by strata. Northwest herring survey, July 2009.

Strata	Imm	Mature	Total
40 D9	2.3	1.2	3.5
40 E0	0.3	0.1	0.4
40 E1	12.4	7	19.4
39 D9	8.1	4.1	12.2
39 E0	2.4	1.2	3.7
39 E1	0.1	0	0.1
38 E0	0	0	0
38 D9	0	0	0
38 D8	0	1.1	1.1
37 E0	0	0	0
37 D9	0	0	0
37 D8	0	6	6
36 D8	0	0.1	0.1
36 D7	0	0	0
35 D8	0	0	0
35 D7	0	0	0
Total	25.6	20.9	46.5
%	55	45	100

Table 8. Herring abundance (millions) at maturity by strata. Northwest herring survey, July 2009.

Strata	Imm	Mature	Total
40 D9	35.75	9.57	45.32
40 E0	3.97	1.06	5.03
40 E1	206.12	52.98	259.10
39 D9	125.24	33.51	158.76
39 E0	37.61	10.06	47.67
39 E1	0.98	0.25	1.23
38 E0	0	0	0
38 D9	0	0	0
38 D8	0	4.72	4.72
37 E0	0	0	0
37 D9	0	0	0
37 D8	0	25.31	25.31
36 D8	0	0.45	0.45
36 D7	0	0	0
35 D8	0	0	0
35 D7	0	0	0
Total	409.67	137.92	547.59
%	74.81	25.19	100

Table 9. Herring biomass and abundance by survey strata. Northwest herring survey, July 2009.

Category Stratum	No. transects	No. schools	Def schools	Mix schools	Prob schools	% zeros	Def Biomass	Mix Biomass	Prob Biomass	Biomass (t)	SSB (t)	Abundance millions
40 D9	4	1	1	0	0	75	3.5	0	0	3.5	1.2	45.32
40 E0	4	2	0	0	2	50	0	0	0.4	0.4	0.1	5.03
40 E1	4	29	22	0	7	0	16.2	0	3.3	19.4	7	259.1
39 D9	9	9	5	0	4	56	1.7	0	10.4	12.2	4.1	158.755
39 E0	9	12	10	0	2	56	3.3	0	0.4	3.7	1.2	47.67
39 E1	4	1	1	0	0	75	0.1	0	0	0.1	0	1.226
38 E0	8	0	0	0	0	100	0	0	0	0	0	0
38 D9	8	0	0	0	0	100	0	0	0	0	0	0.00
38 D8	8	2	0	0	2	88	0	0	1.1	1.1	1.1	4.72
37 E0	3	0	0	0	0	100	0	0	0	0	0	0.00
37 D9	3	0	0	0	0	100	0	0	0	0	0	0.00
37 D8	9	43	0	43	0	78	0	6	0	6	6	25.31
36 D8	9	5	0	5	0	89	0	0.1	0	0.1	0.1	0.45
36 D7	9	0	0	0	0	100	0	0	0	0	0	0.00
35 D8	6	0	0	0	0	100	0	0	0	0	0	0.00
35 D7	6	0	0	0	0	100	0	0	0	0	0	0.00
Total	103	104	39	48	17	81	24.8	6.1	15.6	46.5	20.9	547.59
Cv (%)	-	-	-	-	-	-	-	-	-	34.2	32.2	37.5

Table 10. Boarfish biomass and abundance by survey strata. Northwest herring survey, July 2009.

Category Stratum	No. transects	No. schools	Def schools	Mix schools	Prob schools	% zeros	Def Biomass	Mix Biomass	Prob Biomass	Biomass (t)	Abundance millions
40 D9	4	6	6	0	0	75	0.2	0	0	0.2	20.17
40 E0	4	1	1	0	0	75	0	0	0	0	0.49
40 E1	4	0	0	0	0	100	0	0	0	0	0
39 D9	9	0	0	0	0	100	0	0	0	0	0
39 E0	9	0	0	0	0	100	0	0	0	0	0
39 E1	4	0	0	0	0	100	0	0	0	0	0
38 E0	8	0	0	0	0	100	0	0	0	0	0
38 D9	8	0	0	0	0	100	0	0	0	0	0
38 D8	8	0	0	0	0	100	0	0	0	0	0
37 E0	3	0	0	0	0	100	0	0	0	0	0
37 D9	3	0	0	0	0	100	0	0	0	0	0
37 D8	9	0	0	0	0	100	0	0	0	0	0
36 D8	9	5	5	0	0	78	0.1	0	0	0.1	4.40
36 D7	9	149	149	0	0	11	9.3	0	0	9.3	826.83
35 D8	6	1	1	0	0	83	0.1	0	0	0.1	5.43
35 D7	6	131	131	0	0	17	12.1	0	0	12.1	1142.80
Total	103	293	293	0	0	83	21.7	0	0	21.7	2000.11
Cv (%)	-	-	-	-	-	-	-	-	-	15	16

Table 11. Historic survey time series. Abundance (millions), TSB and SSB (tonnes), age in winter rings. Northwest herring survey, July 2009.

	Spawning Stock survey									*Summer Survey*	
Winter rings	**1999**	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**
0	-	-	5	19.36	-	0.09	1.28	-	-	-	-
1	18.99	10.71	22.69	51.65	10.28	-	7.83	1.6	0.3	6.1	416.35
2	104.77	60.88	52.33	102.93	26.26	3.9	56.91	6.9	3.5	75.9	81.28
3	32.53	48.96	6.41	48.15	30.02	62.35	93.51	86.7	59.8	64.7	11.42
4	11.34	25.57	6.47	10.87	11.08	54.93	109.87	57.5	21.9	38.4	15.06
5	1.65	9.43	2.63	9.17	2.94	80.07	100.8	27.9	11.7	22.3	7.74
6	0.94	2.35	1.94	5.54	0.64	47.14	56.54	16	6.35	26.2	7.09
7	0.3	1.28	0.12	3.95	0.94	13.81	21.16	4.8	1.86	9.1	7.49
8	0.17	0.43	0.24	1.68	0.3	11.77	24.64	4.8	-	5.0	0.4
9	0.11	0.75	0.07	2.06	0.14	-	12.74	1.3	-	3.7	0.9
10+	-	-	-	-	-	-	-	-	-	-	-
TSN (mil)	170.8	160.4	97.9	111.3	82.6	274.1	485.3	202.9	105.4	251.4	547.7
TSB (t)	23,762	21,048	11,062	8,867	10,300	41,700	71,253	27,770	14,222	44,611	46,460
SSB (t)	22,788	20,500	9,800	6,978	9,500	41,300	66,138	27,200	13,974	43,006	20,906

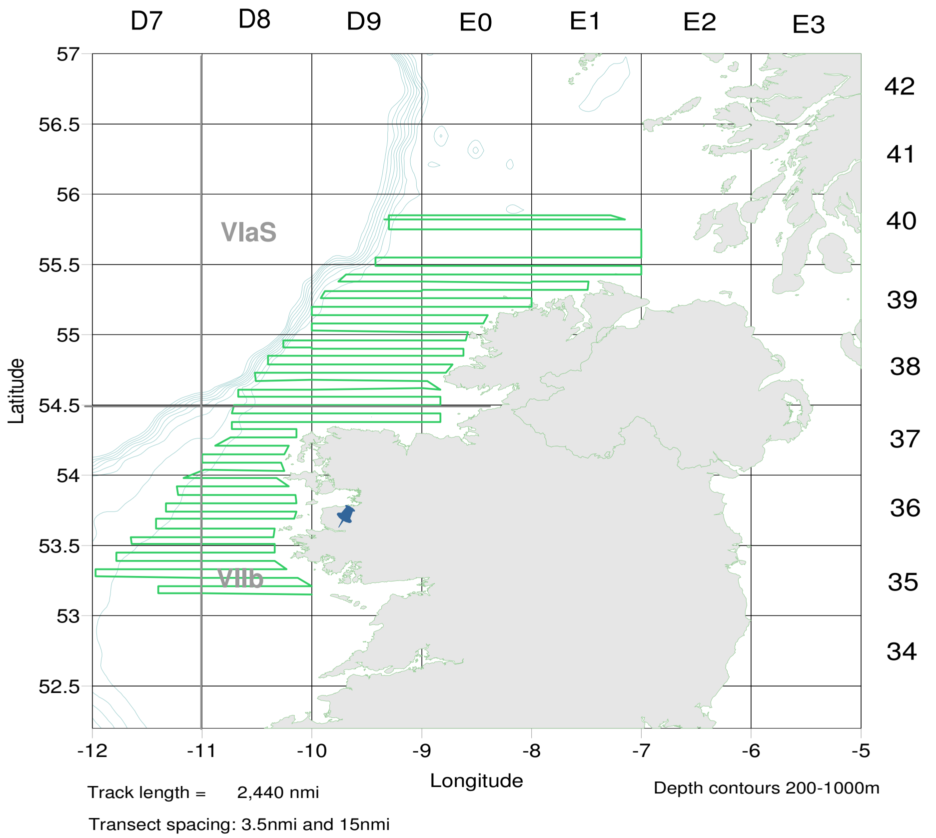


Figure 1. RV Celtic Explorer cruise track. Northwest herring survey, July 2009. Note: Blue pin mark represents calibration site in Killary Harbour.

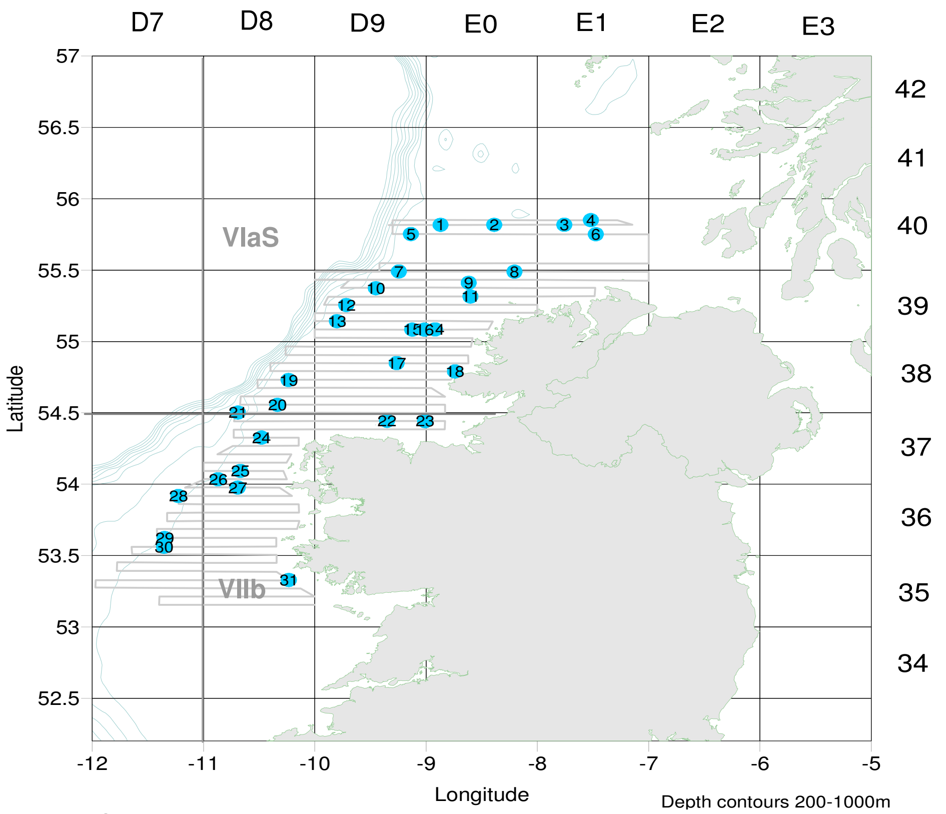


Figure 2. RV Celtic Explorer trawl stations. Northwest herring survey, July 2009.

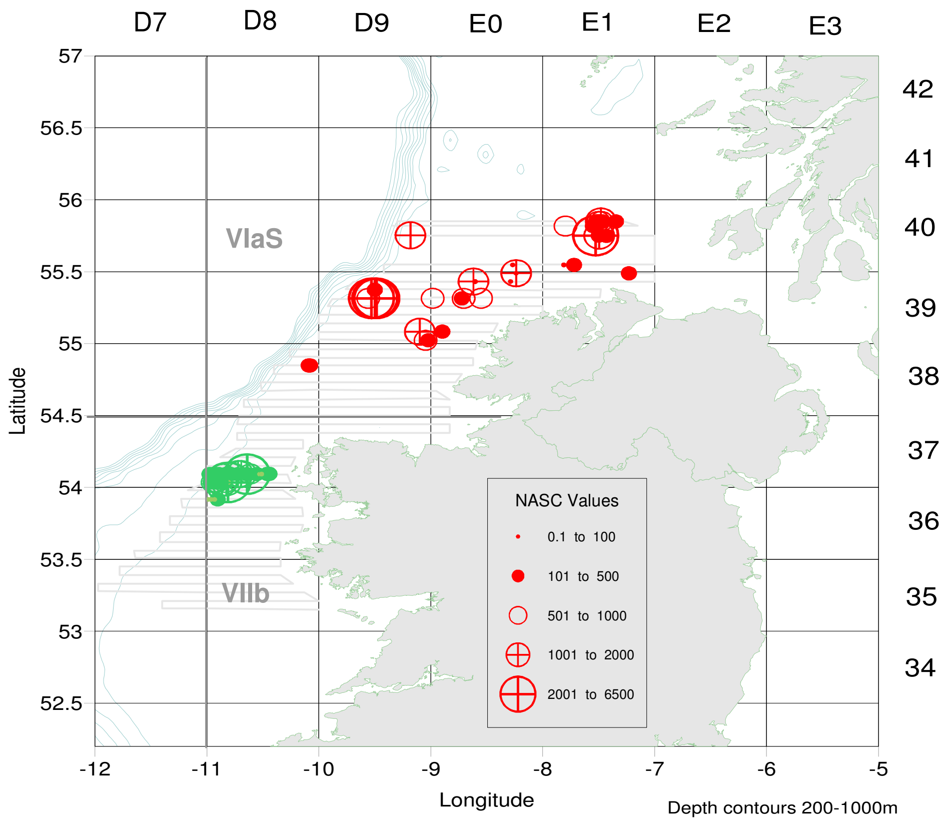
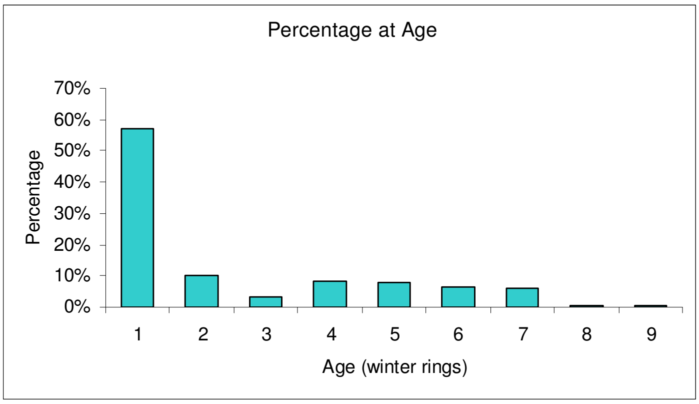


Figure 3. NASC plot of herring distribution. Red circles represent single herring schools, green circles represent herring occurring in mixed schools. Circle size proportional to NASC value. Northwest herring survey, July 2009.



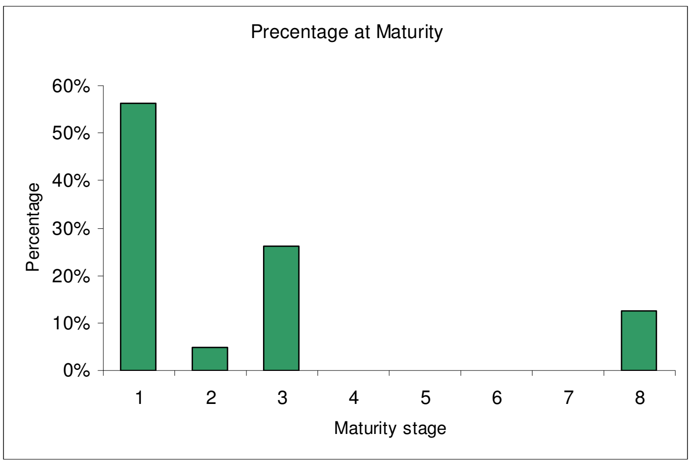


Figure 4. Percentage composition of herring samples at age (top panel) and maturity (bottom panel). Northwest herring survey, July 2009.

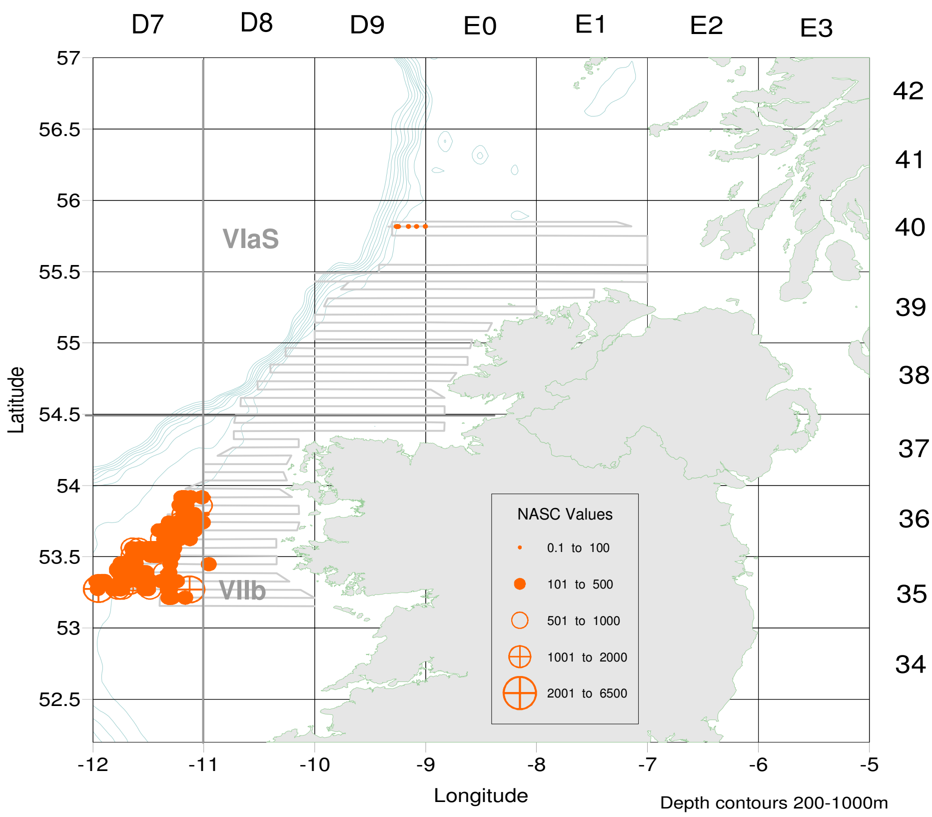
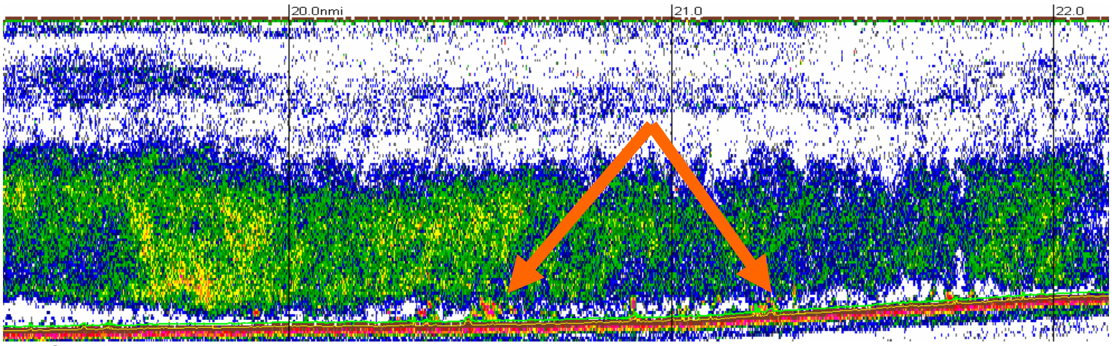
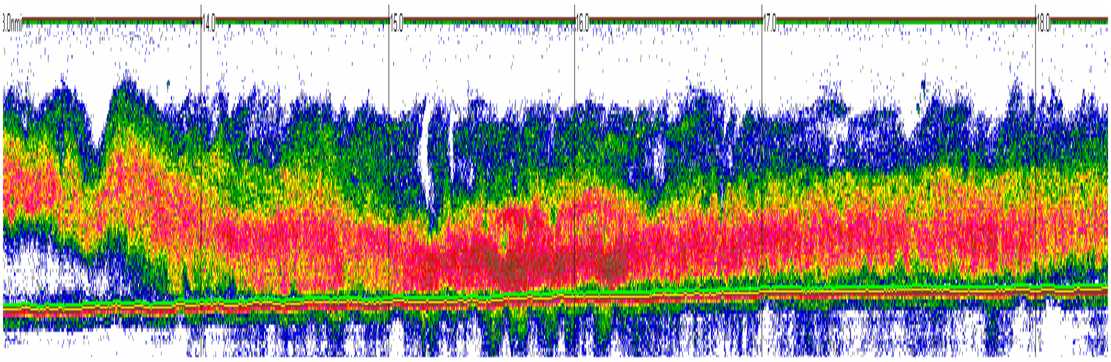


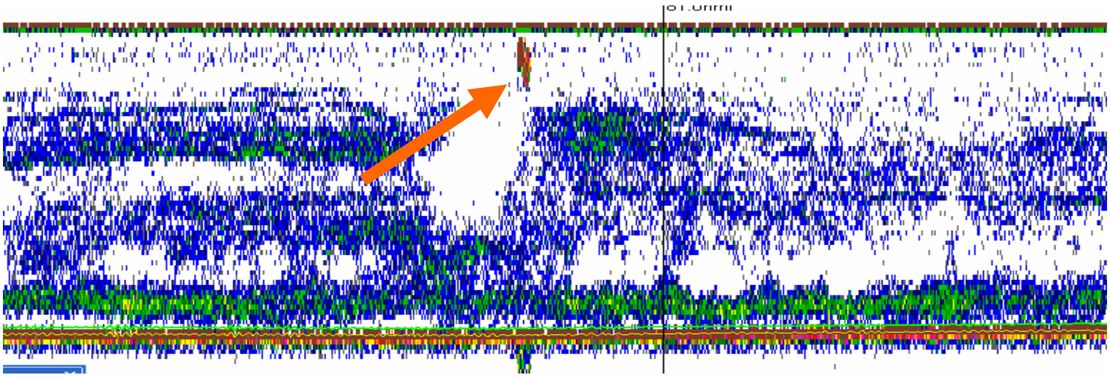
Figure 5. NASC plot of boarfish (*Capros aper*) distribution. Circle size proportional to NASC value. Northwest herring survey, July 2009.



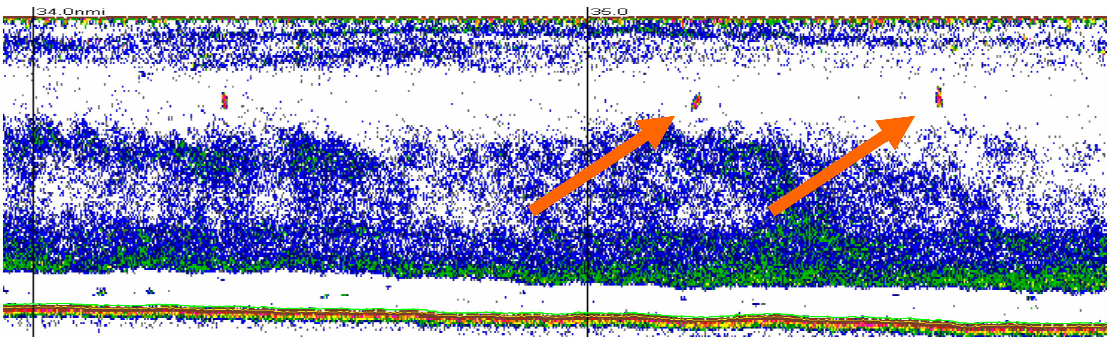
a). *Shelf edge mixed herring schools recorded prior to* ***Haul 25*** *at 10:21. Bottom depth is 185m with targets extending from 0-12m off the bottom. Catch contained 11% herring (See Table 2).*



b). *Very high density scattering layer recorded prior to* ***Haul 01*** *at 08:40. Bottom depth is 122m with targets occurring 0-30m off the bottom. Catch composed of 99.6% mackerel and 0.1% herring (Table 2).*



c). *High-density surface school of herring typical of those encountered along the north coast. Bottom depth is 85m with targets occurring 10-25m from the surface.*



d). *High-density schools of borefish schools typical of those encountered along the shelf slopes from 53-54ºN. Recorded prior to* ***Haul 28*** *a t08:25. Bottom depth is 220m with targets occurring 60m from the surface.*

Figures 6a-d. Echotraces recorded prior to directed trawls. Northwest herring survey, July 2009. Note: vertical bands on echograms represent 1nmi (nautical mile) intervals.

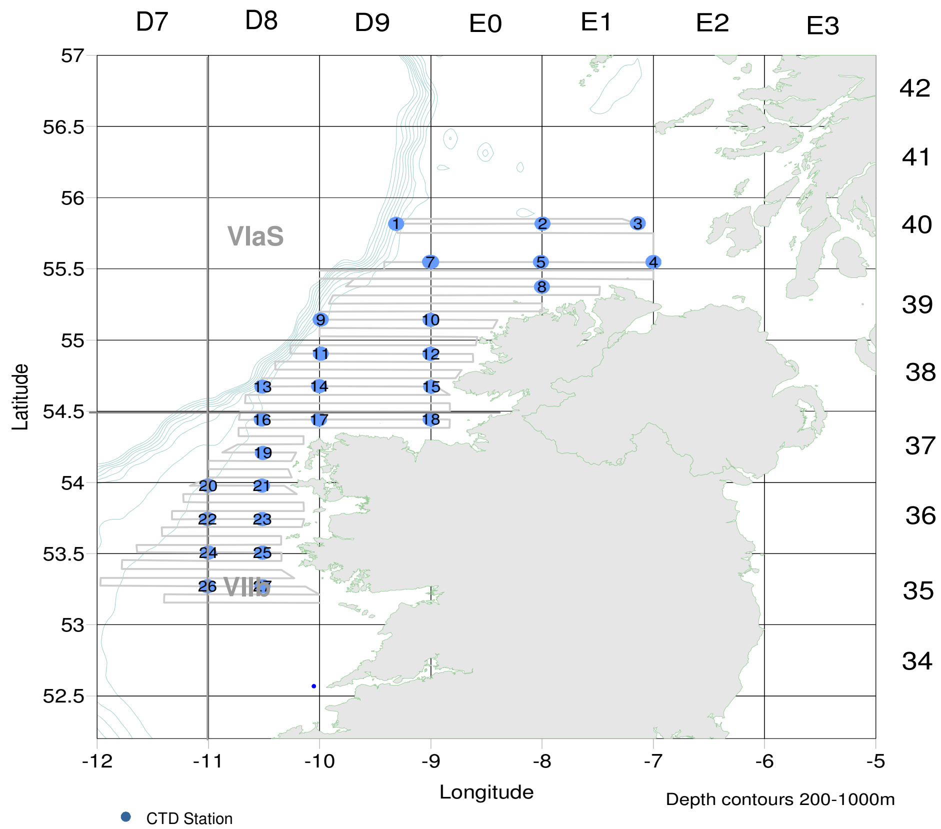


Figure 7. Location of CTD casts. Northwest herring survey, July 2009.

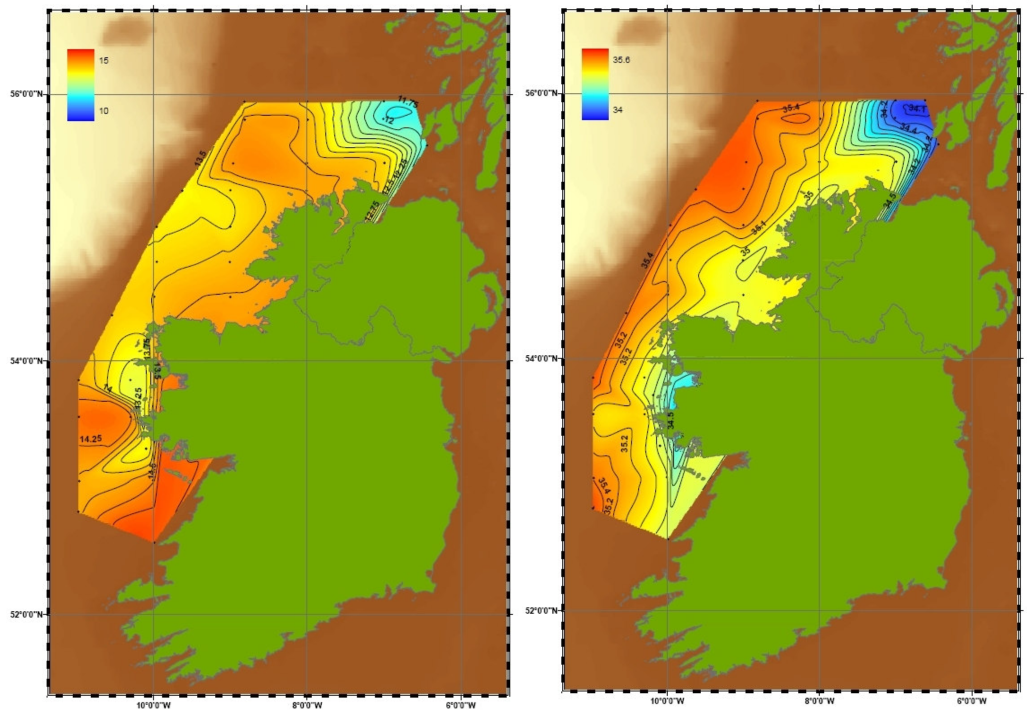


Figure 8. Horizontal temperature (left panel) and salinity (right panel) at 5m subsurface as derived from vertical CTD cast data. Northwest herring survey, July 2009.

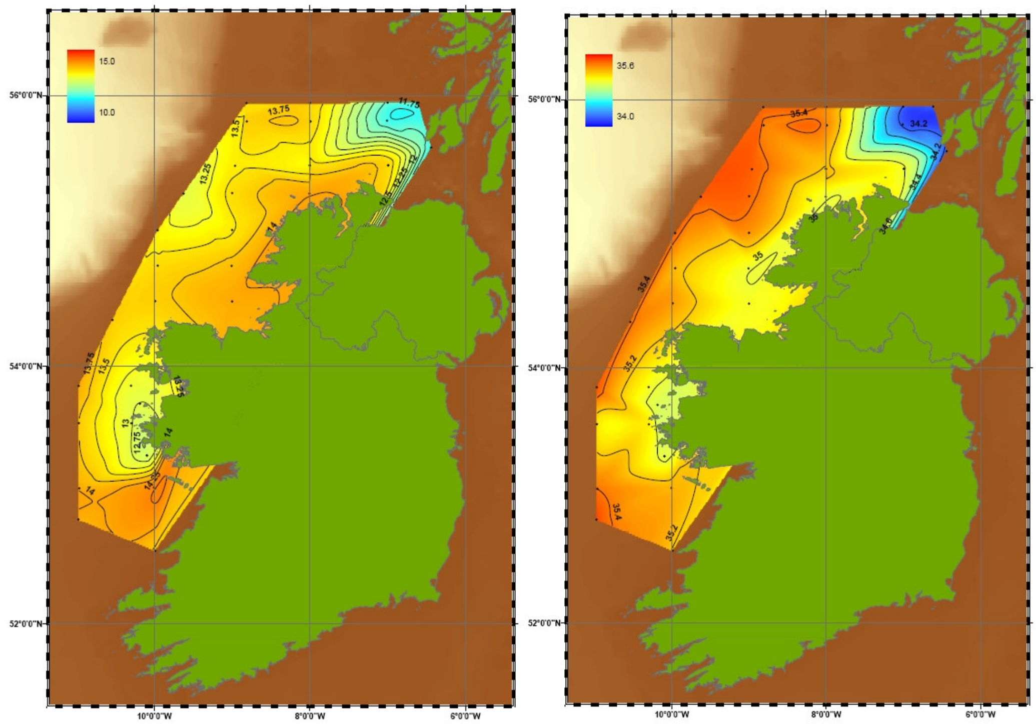


Figure 9. Horizontal temperature (left panel) and salinity (right panel) at 20m subsurface as derived from vertical CTD cast data. Northwest herring survey, July 2009.

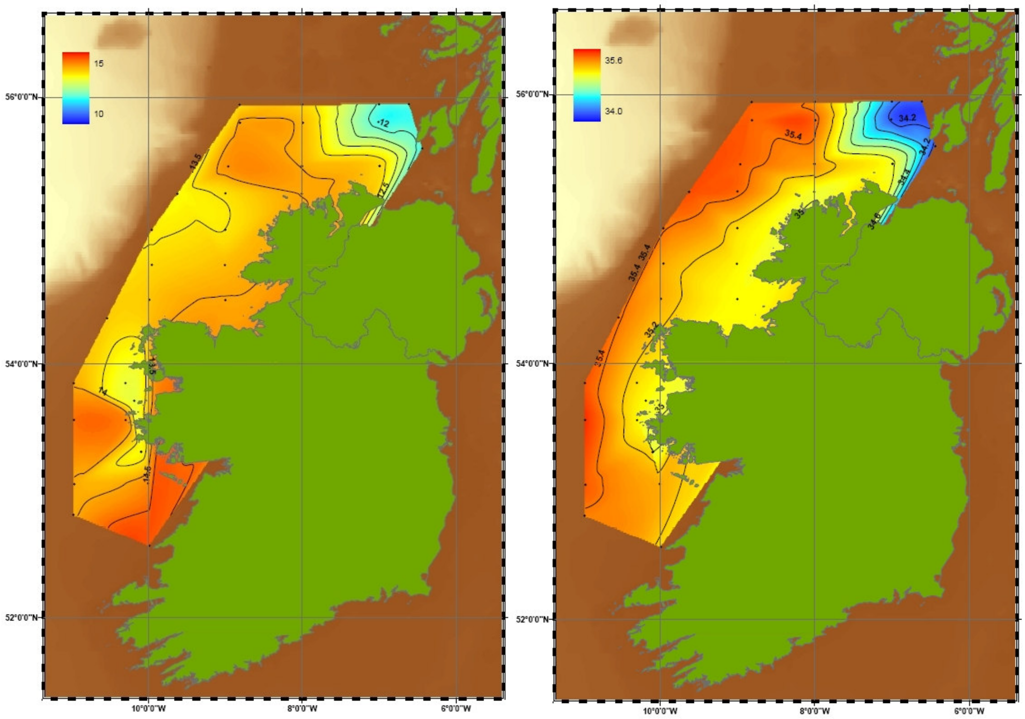


Figure 10. Horizontal distribution of temperature (top) and salinity (bottom) at 40m subsurface as derived from vertical CTD cast data. Northwest herring survey, July 2009.

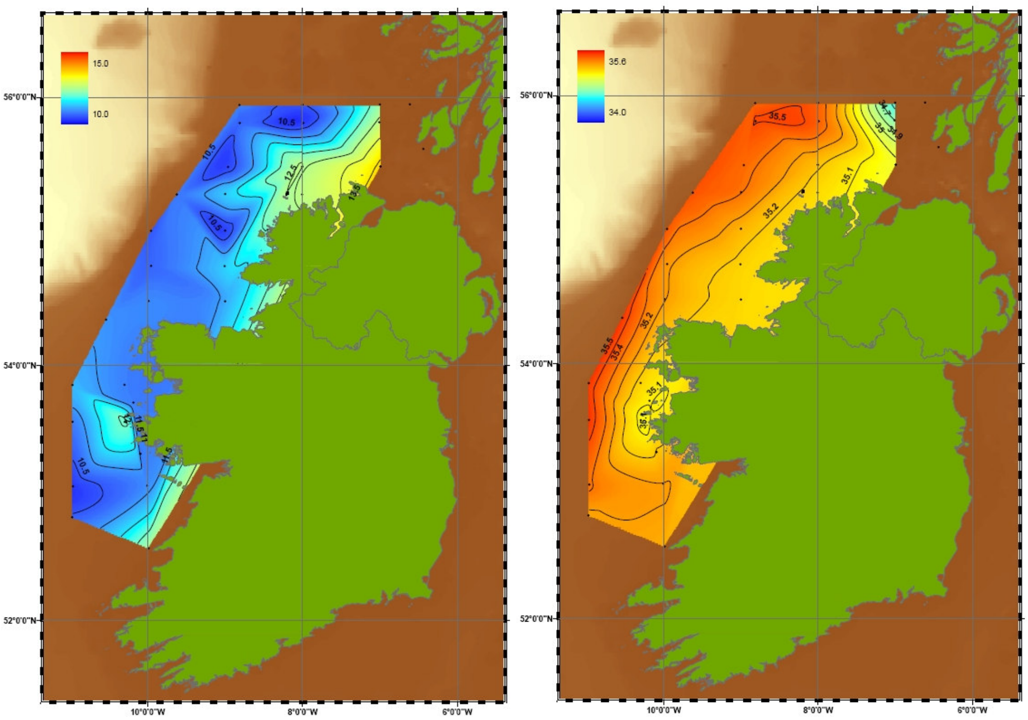


Figure 11. Horizontal distribution of temperature (top) and salinity (bottom) at 60m depth. 100 m depth contour shaded. Northwest herring survey, July 2009.

HERRING MIDWATER TRAWL

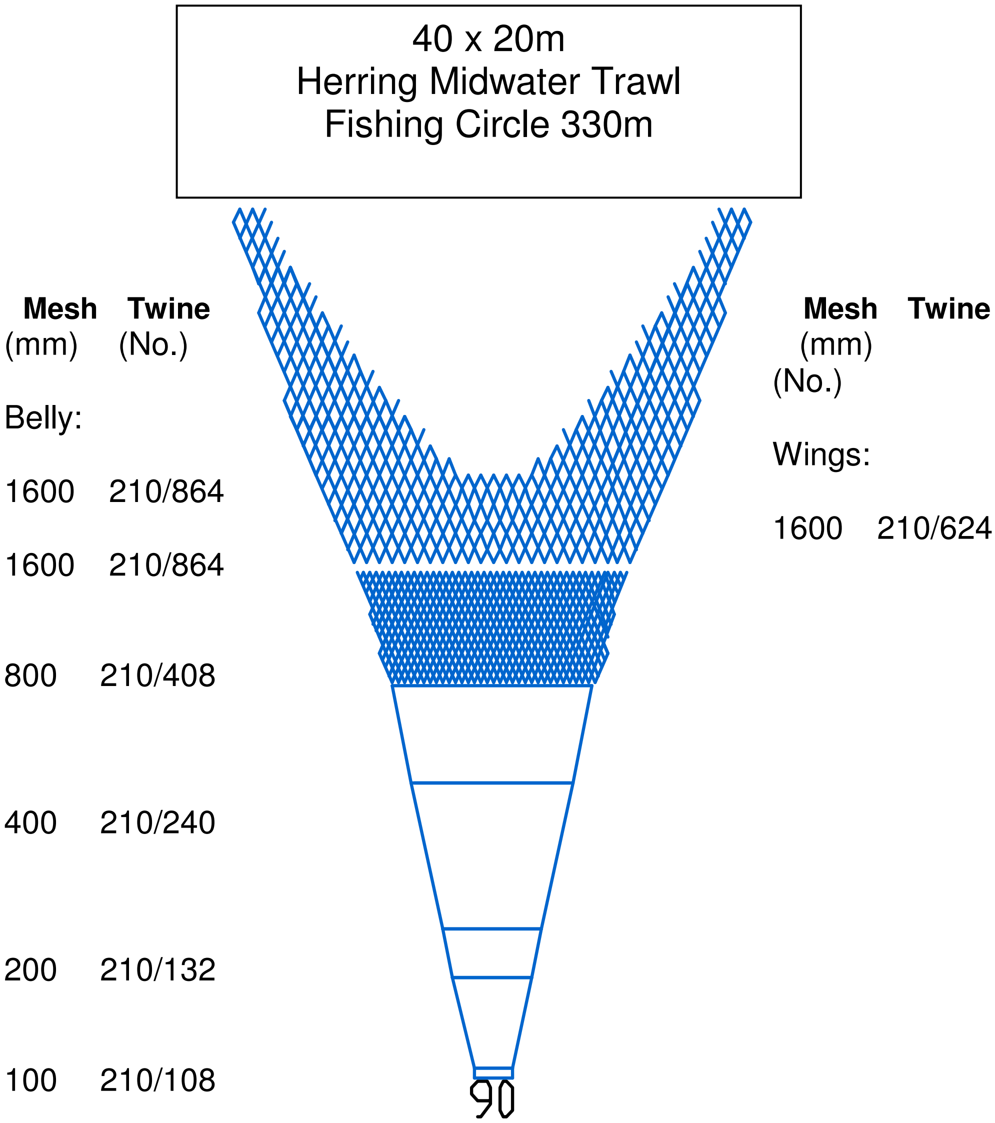


Figure 12. Celtic Explorer herring midwater trawl employed during the Northwest herring acoustic survey, July 2009.